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PRELIMINARY REPORT: WATER NEEDS IN THE RED RIVER OF THE NORTH FOR DOMESTIC AND SANITARY PURPOSES

PUBLIC HEALTH SERVICE
KANSAS CITY, MISSOURI

PREPARED FOR
BUREAU OF RECLAMATION
BILLINGS, MONTANA

JUNE 1949

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A Preliminary Report: Water Needs in the Red River of the North for Domestic and Sanitary Purposes

June 1949

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The effects of the Sheyenne Dam diversion on the water supply and sewage disposal problems near the Sheyenne and Red Rivers are evaluated with respect to how much additional water can be used in the Red River and what monetary benefits can be attributed to this additional flow. Tentative estimates, subject to revision, are provided.

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A PRELIMINARY REPORT

[redacted]

WATER NEEDS IN THE RED RIVER OF THE NORTH FOR DOMESTIC AND SANITARY PURPOSES

PREPARED FOR
REGION 6, BUREAU OF RECLAMATION

BY

Federal Security Agency
PUBLIC HEALTH SERVICE
MISSOURI RIVER BASIN OFFICE
KANSAS CITY, MISSOURI

JUNE 1949

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CONCLUSIONS

As the result of this preliminary study, it is concluded that:

1. The Missouri-Souris development and Sheyenne Reservoir releases to the Sheyenne and Red Rivers will produce extensive public health benefits, many of which are intangible.

2. On the basis of assumptions herein contained, the presently required flow in the Red River at Grand Forks during winter conditions with sugar-beet wastes is approximately 1300 c.f.s. This required winter flow without sugar-beet wastes may be reduced to approximately 300 c.f.s. The presently required summer flow in the Red River at Grand Forks is estimated to be approximately 56 c.f.s. Under each of the above conditions, Grand Forks is the controlling factor in flow requirement in the Red River.

3. On the basis of assumptions herein contained, the required flow in the Red River at Grand Forks during winter conditions with sugar-beet wastes some fifty years in the future is estimated to be approximately 600 c.f.s. On the same basis, the required summer flow in the Red River at Fargo some fifty years in the future is estimated to be approximately 80 c.f.s. In each of the above instances the controlling flow in the river is at the locations given.

4. Summer flow requirements at Grand Forks under existing conditions are greater than at Fargo because Grand Forks has at this time only primary treatment of sewage. With 85 per cent treatment applied, flow requirements at Grand Forks will be less than at Fargo. If Fargo requirements are then supplied, Grand Forks will be automatically accommodated.

5. The annual benefits for sewage dilution for providing the flow required some fifty years hence are estimated to be approximately $700,000.

6. The annual benefits for water supply purposes anticipated from the required flow some fifty years hence are estimated to be $440,000.

7. Extensive additional field and laboratory work will be required for a detailed analyses of benefits which would accrue.

I - INTRODUCTION

1. AUTHORITY

This report is submitted pursuant to a request from the Regional Director, Region 6, Bureau of Reclamation, Billings, Montana, for a preliminary study of the effect of the proposed Missouri-Souris development on the Red River of the North, for inclusion, in part or in toto, in an interim report on the Missouri-Souris, by the Bureau of Reclamation, Region 6.

Since the Red River of the North lies outside the boundaries of the Missouri River Basin, special authority was obtained from the Chief of the Division of Water Pollution Control, Public Health Service, authorizing the Missouri River Basin Office to undertake this work. The report is submitted in compliance with Section 3L of the Memorandum of Understanding between the Bureau of Reclamation, Regions 6 and 7, and the Missouri River Basin Office of the Public Health Service, dated August 31, 1948.

The expenditures for this study were made from funds allocated to the Missouri River Basin Office of the Public Health Service by the Surgeon General. Reimbursement is not contemplated for these expenditures.

2. SCOPE

It was initially contemplated that a complete study would be made of the Public Health implications of the Missouri-Souris development, covering not only the Sheyenne and Red River areas, but the entire area influenced by the development program. Original proposals called for the investigation of all the many sanitary engineering and related aspects of this tremendous development which includes: the diversion of several thousand second-feet of water from the Missouri River near the North Dakota-Montana boundary, across North Dakota; the irrigation of some 1,000,000 acres of land; the collection of waste return flows for subsequent diversion down the James, Sheyenne and Red Rivers; the extensive systems of canals, ditches, dams, pumping stations and hydroelectric developments that make this plan possible; and the supplying of water to municipalities in need of an ample and assured water supply.

It soon became apparent that the limitations of time and funds, and especially the absence of qualified personnel, made it impossible to carry out this huge task in the manner originally proposed. In recognition of the special interest of the Bureau in the sanitary engineering and related implications of the Sheyenne River Dam, and its possible effect on the Sheyenne and Red River basins, it was decided to limit this study primarily to the effects of the Sheyenne Dam diversion on the water supply and sewage disposal problems

along and nearby the main stem of the Sheyenne and Red Rivers.

Specifically, two problems were posed: First, how much additional water can be used in the Red River of the North, both in the near future and fifty years hence, and, second, what monetary benefits can be attributed to this additional flow?

Before it is possible to properly interpret and apply this report, it must be fully understood that the "best answer range" to these apparently simple questions is dependent not only upon prediction of reasonably accurate economic data, such as industrial development and population increase, but also on extended factual data acquired by field investigations, including sampling and gaging studies, as well as certain other scientific investigations of a research character.

Extensive studies of this nature are clearly beyond the scope of this report. Actually, the scope of this study is circumscribed by the best conjecture to the answers to these questions that the judgment and experience of those concerned allows, on the basis of readily available information.

Perhaps it is not possible to rationally ascertain the answers to those questions relating to conditions fifty years in the future because of the natural interrelationship and interdependency of population, industry and water in the Red River Basin. For instance, more water would allow a greater population to exist in the area but an increased population would require more industry for support; which, in turn, would require more water both for supply and for

dilution of wastes; and so the cycle would continue.

This report is therefore limited to a tentative estimate, subject to revision, of the answers to the above problems. It will point out the influencing factors, various tangible and intangible benefits, and set forth, in part, the work that needs to be completed before entirely rational answers can be obtained.

3. SURVEY METHODS

The methods utilized in preparing this report were limited to the accumulation and review of existing and readily available information, statistics and reports; to consultation with individuals of the Bureau of Reclamation and the Departments of Health of the States of North Dakota and Minnesota who are familiar with the multiplicity of problems involved; and to one short field trip through the area to become generally acquainted with the territory.

4. PRIOR REPORTS

The development of the Red River of the North Basin has long been closely allied with problems of water utilization. Undoubtedly it is for this reason that many studies and reports of this area have been prepared. Neither the total number of these reports nor their scope can be readily ascertained.

However, it is known that over 25 separate reports have been written covering, either entirely or in part, the Red River Basin and its attendant water problems. In the preparation of this

report, reference is made to, and use made of, two of this number. They are the "Red River of the North Research Investigation," prepared by the North Dakota State Department of Health, covering the joint investigation by that Department, and the Minnesota State Board of Health in collaboration with the Public Health Service; and the "Report on Survey of the Red River of the North Drainage Basin, Minnesota, South Dakota and North Dakota, for Flood Control and Other Purposes," by War Department, Corps of Engineers, St. Paul, Minnesota.

5. ACKNOWLEDGMENTS AND COOPERATING ORGANIZATIONS

Information and material for the preparation of this report were obtained from the Bureau of Reclamation, Region 6 Office in Billings, Montana, and the District Office in Bismarck, North Dakota; the North Dakota State Department of Health; and the Minnesota State Board of Health. In addition to the above, certain basic information has been obtained from the above-mentioned report of the Corps of Engineers. Information relating to flow in the Red River was furnished by the District Engineer of the North Dakota District of the U. S. Geological Survey and includes all years of record through 1947.

II - DESCRIPTION

1. RED RIVER

The Red River drains an area of approximately 40,200 square miles at the International Boundary. Of this area approximately 21,000 square miles are in North Dakota, 16,400 square miles in Minnesota, 800 square miles in South Dakota, and 2,000 square miles in Canada. Most of this area in Canada is drained by the Pembina River which joins the Red River a few miles south of the International Boundary. The area in North Dakota includes approximately 3,900 square miles of the closed Devils Lake Sub-basin. With the construction of Sheyenne Dam and diversion from this dam through Devils and Stump Lakes, this drainage area would be reactivated.

2. STREAM

The Red River of the North is formed by the confluence of the Boise de Sioux and Otter Tail Rivers at the cities of Wahpeton, North Dakota and Breckenridge, Minnesota. The river flows virtually due north in a meandering path, entering Canada at the juncture of the North Dakota and Minnesota borders. The river flows 394 miles from Wahpeton to the Border, or about twice the airline distance between these two points. Beyond the International Boundary the river flows into Lake Winnipeg, which is drained by Nelson River into Hudson Bay.

One of the principal tributaries of the Red River is the

Sheyenne River which lies in east-central North Dakota and has a drainage area of approximately 7,400 square miles, exclusive of the Devils Lake sub-basin. This river rises in the central part of Sheridan County, North Dakota and flows about 500 miles east, south and northeast to enter the Red River about ten miles downstream (north) from Fargo.

3. TOPOGRAPHY

The Basin consists of two distinct types of topography: a level plain which borders the main stem on both sides; and a more rolling and rougher terrain east and west of the plain. The elevation of the plain varies from approximately 980 feet at the southern end to about 790 feet at the International Boundary, while the upland elevations vary from about 1,200 to 2,100 feet above mean sea level.

4. CLIMATOLOGY

The climate of the basin exerts a profound influence on the entire water supply and sewage disposal problems of this area. The long cold winters and deep frost line increase costs of water distribution. Likewise, thick ice covers are produced on the streams which, contrary to usual conditions, means that the critical period for stream pollution occurs during these winter months. This occurs because the ice cover allows no reaeration whatsoever to take place, except at the few low head dams where the water may be open for a few feet, up and downstream. This means that even small amounts of pollution are significant, since the only

source of oxygen for stabilization of the organic matter is the dissolved oxygen in the stream waters.

The extreme temperatures of the basin vary from -54° to 118°F. The mean annual average temperature varies from 43°F. in the southern part of the basin to 36°F. in the northern portion, with the average for the entire basin being about 39°F.

The average annual precipitation varies from about 24 inches per year in the southeastern part of the basin to 17 inches per year in the northwestern part, with the average for the whole basin being about 20 inches per year. Normally, the greatest amount of precipitation occurs during the period, May through August, and the least amount during the period, December through February.

Average annual evaporation from water surfaces is about 36 inches per year. The average annual runoff for the basin is approximately 1.25 inches but varies from 0.5 inches to 3.5 inches.

Both the time and period of ice coverage are very important. Complete records are not available but, on the basis of data at hand, it appears that complete ice coverage may be expected within the first few weeks of November, and may remain up to the middle of April. The period of complete ice coverage apparently may vary from a minimum of about 100 days to somewhat over 140 days.

5. HYDROLOGY

For the stretch of river between Fargo and Grand Forks (156 river miles), the average stream velocity, without ice cover,

varies from about 10 miles per day, at a discharge of 50 c.f.s. to about 37 miles per day at 5,000 c.f.s. Under conditions of ice cover, the average stream velocity varies from about 7 miles per day, at a discharge of 50 c.f.s. to approximately 25 miles per day at 5,000 c.f.s. discharge.

For the stretch of the river between Grand Forks and Emmerson, Manitoba (146 river miles), the average stream velocity without ice cover varies from approximately 14 miles per day at a flow of 150 c.f.s. to about 42 miles per day at a discharge of 5,000 c.f.s. Under conditions of ice coverage, the average stream velocity varies from approximately 9 miles per day, at a discharge of 150 c.f.s. to about 28 miles per day at a flow of 5,000 c.f.s.

These velocities are, of course, only very general average figures and may be subject to considerable variation, depending on actual conditions. For instance, during summer low-flow periods, the shallow litteral areas and rich organic benthal deposits promote a lush growth of aquatic flora. Such conditions can materially reduce stream velocities.

The slope of the main stem varies from about 1.3 feet per mile in the upper reaches near Breckenridge, to approximately 0.2 feet per mile near the International Boundary, and averages approximately 0.5 feet per mile. In this distance, channel widths vary from 200 to 500 feet and average depths at bankfull stage vary from 10 to 30 feet. Channel capacities are estimated to vary from 1,500 to 20,000 second feet.

The slope of the lower half of the Sheyenne River varies from approximately 1.0 foot per mile from the mouth to river mile 70.0, to approximately 1.5 feet per mile from river mile 70.0 to 245.0. The channel has sufficient capacity above Kindred to carry most flood flows. Below Kindred and Horace to the mouth, the channel capacity, although inadequate for flood flows of from 2000 c.f.s. to 5000 c.f.s., depending upon location and condition, appears adequate to carry any reasonable diversion flows released from Sheyenne Dam.

A preliminary study has been made of the minimum monthly mean flows and the minimum flows, in c.f.s., that can be expected to occur once in every two, three, five and ten years at Fargo and Grand Forks on the Red River of the North. This study is based on information furnished by the District Engineer of the North Dakota District of the Geological Survey. These studies have been made for both summer flows, (June, July, August and September) and winter flows, (November, December, January and February). The period of record for winter flows at Fargo includes the years 1908, 1914, 1915, 1919 through 1923 and 1925 through 1947. The period of record for summer flows at Fargo includes the years 1902 through 1935, and 1937 through 1947. The period of record for the winter flows at Grand Forks includes the years 1883 through 1901, 1903, and 1906 through 1947. The period of record of summer flows at Grand Forks includes the years 1882 through 1901, and 1903 through 1947. The study of the minimum flows includes approximately the

same years of record.

On the basis of these years of record, the minimum monthly mean flow that can be expected to occur at Fargo, North Dakota, for the winter period, once in two, three, five and ten years, is 50, 20, 3 and 0 c.f.s., respectively. The minimum flow, of course, is zero. The minimum monthly mean flow that can be expected to occur at Fargo, North Dakota, for the summer period, once in two, three, five and ten years, is 130, 60, 20 and 5 c.f.s., respectively. The minimum recorded flow is zero.

On the basis of these years of record, the minimum monthly mean flow that can be expected to occur at Grand Forks for the winter period, once in two, three, five and ten years, is 480, 310, 180 and 80 c.f.s., respectively. The minimum recorded flow is 2.9 c.f.s. The minimum monthly mean flow that can be expected to occur at Grand Forks for the summer period, once in two, three, five and ten years, is 830, 470, 240 and 100 c.f.s., respectively. The minimum recorded flow is 20.3 c.f.s.

These preliminary figures are based solely on the above period of record and should be considered as tentative, subject to revision.

III - ECONOMIC CONDITIONS AND TRENDS

1. POPULATION

The 1940 population of the Red River Basin, exclusive of that area drained by the Souris River, was approximately 508,000 according to the 1940 Federal Census. Of this total, 77 per cent was

either rural or rural non-farm.

On the basis of estimates received from the Bureau of Reclamation, Region 6, the 1948 population, in 34 towns having more than 1,000 persons (in 1948), is indicated to have increased 24 per cent over the 1940 population. There has probably been some increase in the rural and rural non-farm population but no information is available upon which to base such an estimate although it is probably less, percentage-wise, than the urban increase.

The population estimates for the towns listed in Table I for the year 2000 A.D. are either taken directly from information furnished by the Bureau of Reclamation or calculated on the same basis; namely, an average increase of approximately 15 per cent over the 1948 populations. These 2000 A.D. population estimates by the Bureau of Reclamation were "based on an evaluation of trends now in effect and the use of a Census Bureau curve of predicted populations under equivalent conditions. Since proportionate population changes have not varied significantly by size of town, it is assumed that all cities will increase at approximately the same rate between 1948 and 2000."

Since these 2000 A.D. population estimates do not consider or make any allowance for the effect of the vast Missouri-Souris development, these estimates must be accepted with due recognition of the fact that they are undoubtedly quite conservative and may not even represent minimum expected populations. In the development of estimates relating to flow requirements and benefits,

TABLE I

POPULATION OF URBAN COMMUNITIES, RED RIVER OF THE NORTH BASIN

Community	Location	Population 1940	1948	2000
Breckenridge, Minn.	Main Stem	2745	3400/	3900/
Wahpeton, N.D.	Main Stem	3747	4100	4699
Moorhead, Minn.	Main Stem	9491	11940	13683
Fargo, N.D.	Main Stem	32580	40725	46671
East Grand Forks, Minn.	Main Stem	3511	4354	4990
Grand Forks, N.D.	Main Stem	20228	25285	28977
Detroit Lakes, Minn.	Ottertail Basin	5015	6200/	7100/
Fergus Falls, Minn.	Ottertail Basin	10848	13400/	15400/
Devils Lake, N.D.	Devils Lake Sub-Basin	6204	8200	9397
Valley City, N.D.	Sheyenne R. Basin	5917	6400	7334
Thief River Falls, Minn.	Red Lake B.	6019	7400/	8500/
Crookston, Minn.	Red Lake B.	7161	8900/	10200/
Grafton, N.D.	Park River B.	4070	5040	5776

/ Calculated on basis of same per cent increase as others in 1948 and 2000 columns. 1948 populations estimated by Bureau of Reclamation except as noted. Populations for the year 2000 A.D. calculated by Bureau of Reclamation except as noted.

population estimates have been so considered. Accordingly annual benefits given in this report are believed to approximate minimums.

The amount of water that can be used in the Red River in the year 2000 depends primarily on the population at that time. This is not necessarily because of the direct demand of that population for water supply and sewage dilution, but rather indirectly upon the water demand of those industries that are responsible for the population increase. It becomes essential, therefore, in any such study as this to have valid population estimates. To predict the population of a single town fifty years in advance is at best a difficult task under normal circumstances. However, to predict the population of an area such as the Red River Basin fifty years in advance, during which time a termendous water development program will take place, requires a lengthy, detailed analysis by competent economists and others. Such an analysis is beyond the scope of this report both in accuracy and time.

Table I shows population estimates for the year 2000 as furnished by the Bureau of Reclamation. These are estimated solely on the basis of "normal" growth. In our opinion the growth that may be anticipated to take place with the Missouri-Souris development will far exceed these estimates. For instance, it is not at all inconceivable that at least 1000 new industrial jobs will be created at Fargo in packing plants, sugar-beet factories, and various other industries allied with agricultural pursuits. Then

according to (unpublished) data and assuming full employment, the population might be expected to increase 10,000 or 15,000 in a decade or so, and yet the fifty-year population increase is estimated at only 6,000.

These voids of available knowledge are pointed out to emphasize the limitations of this preliminary study.

Little consideration is given to rural population in this study; first, because at the present, information is not available which would allow the rational calculation of rural water supply needs or benefits, although they do exist; and second, the rural population of the basin may not have extensive significance from the standpoint of stream pollution.

2. AGRICULTURE

The primary occupation in the Red River Basin is agriculture. Grain farming predominates but dairy, poultry and diversified farming is materially increasing. The proposal to irrigate about one million acres of land in and near the basin will have a profound effect upon the economy. By dividing the land into relatively small tracts it is conceivable that 6,000 - 10,000 or more new farm family units might develop. Information received from the Bureau of Reclamation indicates that the average size farm in the area proposed for irrigation in 1945 was about 600 acres, or a total of about 1,700 farms per million acres. If it is assumed that the farms in the irrigated area will be reduced to about 120 acres each, the total would be 8,300. The difference thus would be

approximately 6,500 farms. The attendant growth of processing and service industries will certainly produce some additional population increase and undoubtedly a portion of this will be centered in the major towns located along the main stem of the Red River.

The growth and expansion of agricultural activities in the Missouri-Souris project is not expected to directly affect, to any considerable degree, the water needs along the main stem of the Red River. The new rural population will, of course, need a supply of water of drinking quality. This may not be available in the area and may have to be furnished, in part, either directly from treated irrigation water or indirectly from underground sources that have been recharged by irrigation water.

The increase in animal population on farms in the irrigated areas, supposedly in conjunction with a diversified irrigated farm program, will increase so-called natural pollution in the streams. It is unlikely, however, that this will have any marked local pollution effects, and doubtful if it will directly affect main stem pollution to any considerable degree. Its principal effect may be to lower slightly the dissolved oxygen available in the dilution water during the winter as that water reaches zones of heavy pollution. This could be significant. For instance, on the basis of subsequent calculations, a drop in dissolved oxygen of 0.3 parts per million (ppm) in the dilution water would require an increase in flow of about 10 per cent.

3. INDUSTRY

The principal industries in the basin are mostly limited to those engaged in the processing of the agricultural products produced in the area. These include creameries, meat packing plants, flour mills, and beet sugar factories. Fargo and Grand Forks are becoming wholesale distributing centers of considerable importance. An increase in population and value of goods produced in the Red River and Missouri-Souris Basins will surely be reflected in growth of these two cities which already are critical pollution sources.

As an example of the importance of industrial development from the water supply and stream pollution standpoints, preliminary estimates indicate that there might be required, in conjunction with diversified irrigated farming, 20 sugar-beet factories, each with an annual capacity of 100,000 tons of beets. Assuming logically that these factories might operate for 100 days at a rate of 1,000 tons per day, each could be expected to require approximately 3.0 million gallons daily, or more of water, and each produce during the period of operation, wastes equivalent to a population of from 126,000 to 230,000 people, depending on the type of process utilized. Even with elaborate and expensive treatment works, including large storage facilities, these treated wastes would present a difficult disposal problem. The seriousness of this problem is emphasized by the fact that normal beet

sugar plant operating periods extend into the period of ice cover in the Red River Basin, which is the most critical period.

Since there are large lignite deposits in North Dakota, the advent of cheap and readily available power might presage the development of large synthetic fuel manufacturing plants. These in turn would influence population growth and might contribute wastes which, although small in quantity, would require large amounts of dilution water or expensive treatment to make the receiving stream a suitable source of water for domestic purposes. Furthermore, even small plants, such as creameries, dairies and packing plants produce wastes which are quite significant from the standpoint of stream pollution.

The industrial development of the Red River Basin may well hinge on the ability of the Red River to receive, without extensive detriment, the wastes from these industries.

IV - WATER SUPPLY

1. GENERAL

During the past two decades the Red River Basin has experienced both drouth and flood conditions. The periods of excessive rainfall are not of special interest in this report. The drouth of the thirties was the most severe on record and emphasizes the importance of water and man's dependence on it not only for his livelihood but for his very life.

During this drouth period many of the tributaries of the Red River ceased to flow. Even in the Red River at Fargo there were extended periods of no flow. For the towns using surface water as sources of public supply, the low flow conditions were especially serious, not only because of the decrease in quantity, but also because of the lowered quality of the water. In some instances, even though a small amount of water was present, it was virtually impossible to treat it in such a manner as to produce a potable supply.

Underground water sources in many instances either failed, produced water of undesirable quality, or had seriously reduced yields. Geological investigations have indicated with a reasonable degree of certainty that underground water sources cannot be relied upon to meet the increasing water requirements of the larger municipalities in the Red River Basin.

Generally speaking, additional dependable supplies of water in the areas bordering Devils Lake and the Sheyenne and Red Rivers have, for water supply purposes, significantly greater than average values.

2. RURAL

Rural water supply in the area under study generally presents a special problem. Rural residents traditionally depend on underground sources for water. In this area ground water is not readily obtainable. In some sections water that is available is undependable

as to quantity and undesirable as to chemical and physical quality.

During the drouth, especially along the Sheyenne River but also along the Red River, farmers could not obtain water for stock and, as a result, many animals either perished or had to be sold.

Storage facilities that could assure required flows in these streams during drouth periods would have considerable value for rural water supply purposes alone. However, no rational method, based on present information, is available for calculating the dollar value of these benefits. Therefore, an investigation of the dollar value of water for water supply in rural areas along the Sheyenne and Red Rivers is beyond the scope of this report.

In the irrigated areas the recharge of ground water by applied irrigation water likewise will have considerable value for rural water supply purposes. However, the detailed study necessary for the rational calculation of such benefits is beyond the scope of this preliminary study.

MUNICIPAL

The undependability of existing water sources has been most keenly realized in the cities. History has proven that an adequate potable water supply is one of a city's greatest assets and that, without such a supply, growth is impossible. During periods of very low flow, such as occurred in the Red River during the thirties, consumption of water in towns like Fargo and Grand Forks had to be drastically reduced. These reductions in consumption

are frequently accompanied by pressure reductions in the distribution system, a condition conducive to water-borne epidemics.

Table II lists the municipalities in the Red River Basin having surface water supplies that could be benefited by increased flow in the Sheyenne and Red Rivers. Although Wahpeton and Breckenridge have apparently relieved their water supply problems, a repetition of severe drouth conditions might find them short of water. Even though they are above the junction of the Sheyenne and Red Rivers, it is conceivable that increased flow in these rivers will be of some benefit to these two cities for water supply purposes. However, no dollar value is assigned to these benefits in this study. The remaining cities in Table II have an estimated present population of 71,350. In view of the frequency and quantity of minimum monthly mean flows in the Red River at these cities, the extreme importance of a dependable potable water supply to urban life, and further considering the limitations of inadequate water supply both from the standpoint of quality and quantity on the growth of these cities, it is reasonable to assign some value to an assumed increased flow sufficient to alleviate these conditions. Actually, the controlling quantity of "required flow" will be that required for sewage dilution but this in no way detracts from the value of the increased flow for water supply purposes.

The assignment of a value to this flow in such a preliminary

TABLE II

MUNICIPAL SURFACE WATER SUPPLIES ON MAIN STEM OF THE RED RIVER *

Municipality	State	1948 Est. Pop. Served	Treatment	Remarks
Wahpeton	N.D.	4500	F D	History of inadequate source
Breckenridge	Minn.	3000	F D H	History of inadequate source
Fargo	N.D.	41000	F D H	Inadequate supply
East Grand Forks	Minn.	4300	F D H	Poor source at low flow
Grand Forks *	N.D.	25000	F D H	Poor source at low flow
Drayton	N.D.	500	F D H	Poor source at low flow
Pembina	N.D.	550	F D	Poor source at low flow
Total - - - - -		78850		

F - Coagulation, Sedimentation, Filtration

D - Disinfection

H - Softening

* Normally Grand Forks secures approximately 70 per cent of its water supply from Red Lake River. However, the city is wholly dependent upon the Red River of the North for a water source during periods of very low flow in Red Lake River.

study as this is indeed most difficult. It is further complicated by the fact that there is no alternate source whereby the cost of developing the alternate supply might be compared to the value of the increased flow. As an example, however, Fessenden, North Dakota spent about $250 per capita developing a water supply that is not entirely adequate. Moorhead, Minnesota, spent an estimated $25 per capita developing a supplementary supply. The "Nationwide Inventory of Sanitation Needs", published by the Public Health Service in 1946, estimates the per capita cost of new water works systems needed in the State of North Dakota at $125 and in Minnesota at $236. The average of these two figures is about $180 per capita. If it is assumed that one third of this can be assigned in this case to the source of supply, then the per capita cost is $60. Taking these and other factors, such as the cost of developing numerous private water supplies, and reduced costs of operating water treatment plants with improved quality of raw water, into consideration, it appears logical to assign a capital cost benefit of at least $50 per capita for the 71,350 people previously referred to, for increased flows in the Red River sufficient to maintain satisfactory conditions in the stream. (The approximate quantity of this flow is developed in the section referring to stream pollution). On this basis, the capital cost of developing equivalent benefits is estimated to be $3,600,000. If maintenance and operating charges are estimated at 2 per cent with interest at 3 per cent, and assuming a life of 30 years for

amortization, the annual benefit is approximately $256,000.

To the above must be added the benefit, for water supply purposes, accruing to the towns listed in Table III, having a total population of 31,750. It is recognized that some of these towns may be too far from the source to use it economically and some may not care to develop a public supply to supplement the one they have. However, for the purpose of this report, it is assumed that some benefit will accrue to each of these towns by virtue of a dependable water source being available.

The same problems arise here as before when trying to assign a dollar value to these benefits except that in many cases in these towns there is no existing supply nor is one available. The value of a new supply might be compared to the cost of bottled water for drinking and culinary purposes. In Devils Lake, for instance, bottled drinking water sells for $0.05 per gallon. The assumption that two gallons per day per person is used for drinking and culinary purposes only, results in an annual cost of approximately $35 per capita, or when capitalized at 5 per cent, a capital cost of $700 per capita. Even this huge charge would not provide a supply that approaches the benefits of a dependable potable public supply.

Considering these, and other factors, such as the smaller size of these towns, it appears logical to assign a capital cost benefit of at least $100 per capita to, say two-thirds of the population listed in Table III, or approximately 20,000 people. On this

TABLE III

MUNICIPALITIES, OTHER THAN THOSE LISTED IN TABLE II, ON OR NEAR MAIN STEM OF RED AND SHEYENNE RIVERS THAT EITHER HAVE NO WATER SUPPLY OR AN INADEQUATE SUPPLY

Municipality and State	Stream	Miles from Water Source	Est. 1948 Pop.	Remarks
Aneta, N.D.	Sheyenne	7	550	No water
Binford, N.D.	Sheyenne	10	350	No public supply
Buxton, N.D.	Red	12	450	Poor water - no public supply
Casselton, N.D.	Sheyenne	15	1500	Highly mineralized water
Cooperstown, N.D.	Sheyenne	6	1150	Poor water (dug wells)
Davenport, N.D.	Sheyenne	5	150	No public supply
Dazey, N.D.	Sheyenne	10	250	No public supply
Devils Lake, N.D.	Devils Lake	0	8200	Water very poor - not used for drinking
Enderlin, N.D.	Sheyenne	10	1600	Limited source
Esmond, N.D.	Sheyenne	2	500	Only poor water now available
Fingal, N.D.	Sheyenne	10	300	No public supply - water difficult to obtain
Gardner, N.D.	Red	7	100	No public supply - hard to get satisfactory water
Grafton, N.D.	Red	12	5000	Very poor water - no satisfactory supply available

TABLE III (Cont'd)

Municipality and State	Stream	Miles from Water Source	Est. 1948 Pop.	Remarks
Grandin, N.D.	Red	10	150	No public supply - difficult to obtain water in this area
Hamilton, N.D.	Red	13	250	No public supply
Hannaford, N.D.	Sheyenne	10	400	No public supply - poor water in this area
Kindred, N.D.	Sheyenne	2	500	No public supply
Lakota, N.D.	Devils Lake	8	1050	Poor water
Lisbon, N.D.	Sheyenne	0	2100	Highly mineralized water - limited quantity
Litchville, N.D.	Sheyenne	12	450	No public supply
Luverne, N.D.	Sheyenne	4	200	No public supply
Maddock, N.D.	Sheyenne	8	700	No public supply
Manvel, N.D.	Sheyenne	5	200	No ground water available
Milnor, N.D.	Sheyenne	10	700	No public supply - poor water available
Minnewaukan, N.D.	Devils Lake	0	550	No water source available
Minto, N.D.	Red	12	650	Only poor water available
Nome, N.D.	Sheyenne	6	300	No public water supply

TABLE III (Cont'd)

Municipality and State	Stream	Miles from Water Source	Est. 1948 Pop.	Remarks
Pekin, N.D.	Sheyenne	3	300	No public supply
Reynolds, N.D.	Red	10	350	Only poor water available
Rogers, N.D.	Sheyenne	10	200	No public supply
St. Thomas, N.D.	Red	16	500	Only poor ground water available
Sharon, N.D.	Sheyenne	10	400	No public supply
Sheyenne, N.D.	Sheyenne	0	450	No public supply
So. West Fargo, N.D.	Sheyenne	0	750	Present wells dry
Thompson, N.D.	Red	8	300	No public supply - poor ground water area
Warwick, N.D.	Canal Devils Lake	5	200	No public supply
	Total - - - - - -		31750	

basis the capital cost of developing equivalent benefits is estimated to be $2,000,000. The annual benefits may be calculated on the same basis as before to be equal to $142,000.

The total preliminary benefits to water supply as a result of increased dependable flows in the Sheyenne and Red Rivers and Devils Lake can be considered to be $398,000 per year on the basis of 1948 population. There is a wide latitude in the reasonable choice of a per capita benefit that might be assigned for water supply. The population increase by the year 2000 A. D. might be limited to 15 per cent in the larger cities and probably much less in the smaller ones. The effect of population growth on economic benefits is therefore considered of secondary importance. Accordingly, the benefits based on 1948 populations may reasonably be increased by 10 per cent to account for population increase to year 2000 A. D. This would raise the total benefits to $437,800, which, rounded to the nearest significant figure, is used as $440,000. This may be considered a minimum figure that does not include many tangible benefits such as reduced treatment costs of existing supplies, probable lowered fire insurance rates, increase in values and consequent increased tax revenues of real estate as a result of industrial expansion and population increase, the reduction in hazard of water-borne epidemics, reduced cost of softening water due to release of lower hardness water stored during periods of runoff, the aesthetic value of a less polluted water

supply, and other related factors.

By means of a unique analysis the Corps of Engineers have, in a report of the Red River previously referred to, estimated annual benefits to water supply due to coordinated increased flows to be $223,000. This applies only to certain of the larger cities in the Basin, and may be considered as comparable to the above figure when extended to cover the larger area.

It has been stated by the Minnesota Department of Health that, "Over the next period of fifty years, the problem of obtaining additional water supplies may be expected to be the controlling factor in industrial development of the area" (Red River Basin).

4. INDUSTRIAL

Measurement of the benefit of a water supply that enables a new industry, such as sugar-beet factory, to locate in an area does not lend itself readily to rational analysis and perhaps is more appropriately the function of an economist rather than a sanitary engineer. As an example, however, a sugar-beet factory of usual capacity may require a quantity of water equal to that used by a town of 50,000 people during the period of operation of the factory. The location of new industry in an area, as has been pointed out, increases the population and wealth of the community and is certainly an asset. Therefore, availability of a new water supply to be used by the industry may be considered to have at

least a portion of the value of the industry when that industry's location in the area is dependent upon an additional water supply. In the case of most industry that is interested in locating in the Red River Basin, namely, those concerned with processing agricultural products, another large portion of the benefit to that industry must be assigned to the provision of adequate dilution water for disposal of the industrial wastes.

It is true that industries such as sugar-beet factories and packing plants requiring large volumes of water now want to locate in the Red River Basin, mainly along the main stem, but cannot, partly because of water supply demands and partly because of the need for sewage dilution water.

Actually, it is beyond the scope of this report even to attempt an estimate of the benefit of additional water supply for industrial uses, especially in lieu of the complete absence of information relative to the anticipated industrial expansion as a result of the Missouri-Souris development. It can be stated categorically, however, that the value of such additional water as may be provided by the Missouri-Souris development in the Sheyenne and Red Rivers for industrial use might well be a major fraction of or even exceed the minimum tangible benefits assigned for municipal water supply purposes.

5. DISCUSSION

The diversion of enough water into the Sheyenne and Red Rivers to provide adequate sewage dilution at all times will be

the controlling factor in the quantity of water that can be used or is needed for sanitation purposes in the Sheyenne and Red Rivers during the next half century. Nevertheless, there is a critical and immediate need for an increased minimum flow of water for water supply purposes and such flow has tangible and extensive intangible benefits as mentioned previously.

The provision of a dam with sufficient storage capacity to insure increased minimum flows in the Red River, such as the Sheyenne Dam, may well presage a new era of expansion for the Red River Basin. Thus water supply and related benefits are extremely important.

V - SEWERAGE AND STREAM SANITATION

1. GENERAL

The disposal of sewage by dilution has long been a recognized method for rendering innocuous the waste products of people and industry. Many factors enter into the consideration of the amount of dilution necessary. In most inland water courses there is insufficient dilution water available, and "downstream" uses require some degree of sewage treatment in conjunction with the dilution. This condition exists in the Red River of the North.

On streams such as this, a high degree of sewage treatment is essential to maintain a water that: is safe to use as a source of raw water for water supply purposes; will meet accepted public

health requirements; will support fish and aquatic life; will be generally inoffensive to the riparian residents and casual users; and will meet esthetic standards.

No method of sewage treatment exists today whereby it is economically feasible to remove all deleterious matter, both chemical and biological, from sewage, such that no dilution water is required for its satisfactory disposal under conditions of use existing in the Red River of the North. It becomes necessary, therefore, to arrive at some balance between degree of sewage treatment and dilution afforded the effluent, keeping in mind the quality of water that use demands.

The Inter-State Sanitation Committee represented by the State Health Departments of North and South Dakota and Minnesota, and other State representatives, has recommended that industries and municipalities treat their sewage to such a degree that the average Biochemical Oxygen Demand of the effluent does not exceed 25 ppm, and the suspended solids do not exceed 30 ppm with no peaks exceeding twice these amounts. In the case of municipalities without undue volumes of industrial wastes being discharged into the municipal sewer systems, these limits represent approximately the degree of treatment that can be attained by what is termed secondary treatment. The wastes from certain industries, or undue proportions of many industrial wastes, can, however, render these limits unattainable by secondary treatment methods. Further

treatment is required, therefore, and can be referred to as tertiary treatment.

Even effluents that meet the above limits require dilution water. Under summer conditions when reaeration of the stream occurs, relatively small unit volumes of dilution water will, after secondary treatment, satisfy the remaining oxygen demand in the sewage effluent. Under conditions of winter ice cover, which excludes reaeration, relatively large amounts of dilution water are required to maintain the stream in an acceptable condition.

The organic matter that enters a stream, either as "natural pollution" from surface runoff, or as sewage, requires oxygen for its stabilization. This oxygen is obtained from the water, either from "free or dissolved oxygen" or from oxygen combined chemically with other substances in the water. If a sufficient amount of dissolved oxygen is not present, the dissolved oxygen is first depleted, and organic decomposition then takes place under anaerobic conditions. These anaerobic conditions are accompanied by multiplication of certain bacteria and the production of foul smelling gases such as hydrogen sulphide and mercaptans. This produces an environment untenable to fish, as well as other undesirable conditions. In addition, the water is unfit for use as a source of water supply, and frequently cannot even be used for stock watering.

Even with secondary treatment of all sources of sewage, or its equivalent for industrial wastes, it will still be necessary to provide additional dilution water in the Red River to prevent undesirable conditions in the stream, or to provide a lesser amount of dilution water and more treatment. For a given amount of pollution and secondary treatment, a certain volume of dilution water will be required to maintain desirable conditions. As developed above, secondary treatment should be provided in the Red River Basin. If, however, tertiary treatment is provided by means of additional units, such as secondary sedimentation basins and intermittent sand filters, a reduced amount of dilution water is required. The cost, therefore, of these tertiary treatment units may be compared to the value of the dilution water furnished which makes the tertiary treatment units unnecessary.

Such studies and comparisons have been made in this report. This yields an amount which represents the minimum tangible benefits to be derived from supplying water sufficiently in excess of ten-year minimum mean monthly flows to maintain acceptable conditions in the River.

These acceptable conditions have been defined in the Red River of the North Research Investigation Report previously referred to as a minimum average dissolved oxygen content of 3 ppm. This is indeed a minimum level, since various authorities consider average dissolved oxygen concentrations of 4-5 ppm are

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necessary to support even rough fish. The use of this figure of 3 ppm, however, makes the benefit analysis even more conservative and in the absence of supporting field data, will be used in this study.

2. MUNICIPAL

Table IV contains a list of the sources of pollution, the receiving stream or sub-watershed, treatment facilities and estimated population equivalent of wastes discharged. This is merely a preliminary estimate based on the best knowledge of the engineers of the North Dakota and Minnesota State Health Departments, and must eventually be supplanted by detailed field investigations. The two critical points along the stream are at Fargo and Grand Forks. For the purpose of this study it is assumed that dilution water entering the Red River below Fargo from the Sheyenne River is satisfactory, or that there will be provided a channel to divert water from the Sheyenne to the Red River above Fargo.

The total population equivalent entering the streams of the basin, according to Table IV, is estimated to be 455,000. A considerable portion of this comes from seasonal industrial wastes but, since that coincides with the time of ice cover, the most critical period for the stream, it is included.

3. INDUSTRIAL

Industrial wastes known to be discharged outside of municipal sewer systems are listed in Table IV. These are most significant.

TABLE IV

RED RIVER OF THE NORTH BASIN

SOURCES OF POLLUTION

Municipality	State	Stream	Treatment Facilities	Est. Pop. Equ. of Waste	Remarks
Harvey	N.D.	Sheyenne	None	2,500	
Cooperstown	N.D.	Sheyenne	Septic Tank	1,500	
S.W. Fargo	N.D.	Sheyenne	None	2,500	No sewer system now
Enderlin	N.D.	Sheyenne	Septic Tank	2,500	
Maddock	N.D.	Sheyenne	None	1,500	No sewer system now
Kindred	N.D.	Sheyenne	None	450	No sewer system now
Lisbon	N.D.	Sheyenne	Secondary	500	
West Fargo	N.D.	Sheyenne	Secondary and Tertiary (partial)	2,500	Including Armour Packing Plant
Valley City	N.D.	Sheyenne	Secondary	1,500	
Fairmont	N.D.	Bois de Sioux	Septic Tank	1,200	
Wahpeton	N.D.	Bois de Sioux	Primary and Filter	1,000	
Fargo	N.D.	Red	Primary and Filter	9,000	

TABLE IV (Cont'd)

Municipality	State	Stream	Treatment Facilities	Est. Pop. Equ. of Waste	Remarks
Grand Forks	N.D.	Red	Primary on Municipal. None on Indust.	63,600	
E. Grand Forks	Minn.	Red	None	6,000	
Am. Crystal Sugar			Lagoon	140,000	
Moorhead	Minn.	Red	Secondary	28,000	
Am. Crystal Sugar			Lagoon	90,000	
Dilworth	Minn.	Red	Secondary	1,100	
Wolverton	Minn.	Red	Primary	200	
Breckenridge	Minn.	Red	None	3,500	
Hallock	Minn.	Two Rivers	None	1,500	
Lancaster	Minn.	Two Rivers	None	500	
Warren	Minn.	Snake R.	None	2,500	
Argyle	Minn.	Middle R.	None	900	
Crookston	Minn.	Red Lake R.	None	8,000	
Red Lake Falls	Minn.	Red Lake R.	Primary	2,000	

TABLE IV (Cont'd)

Municipality	State	Stream	Treatment Facilities	Est. Pop. Equ. of Waste	Remarks
Thief River Falls	Minn.	Red Lake R.	Secondary	8,750	
Fosston	Minn.	Red Lake R.	Secondary	2,500	
Fertile	Minn.	Sand Hill R.	None	1,000	
Climax	Minn.	Sand Hill R.	Primary	250	
Ada	Minn.	Marsh River	None	1,780	
Mahnomen	Minn.	Wild Rice R.	None	2,000	
Twin Valley	Minn.	Wild Rice R.	None	900	
Hawley	Minn.	Buffalo R.	None	1,800	
Barnesville	Minn.	Buffalo R.	Secondary	1,800	
Fergus Falls	Minn.	Otter Tail R.	Primary	17,500	
Frazee	Minn.	Otter Tail R.	Primary	1,500	
New York Mills	Minn.	Otter Tail R.	Secondary	1,777	
Perham	Minn.	Otter Tail R.	Secondary	2,500	

TABLE IV (Cont'd)

Municipality	State	Stream	Treatment Facilities	Est. Pop. Equ. of Waste	Remarks
Wheaton	Minn.	Mustinka R.	None	1,900	
Graceville	Minn.	Mustinka R.	Primary	1,100	
Elbow Lake	Minn.	Mustinka R.	Primary	1,200	
Herman	Minn.	Mustinka R.	None	750	
Donnelly	Minn.	Mustinka R.	None	400	
Detroit Lakes	Minn.	Pelican R.	Secondary	8,300	
Pelican Rapids	Minn.	Pelican R.	Secondary	2,500	
Rothsay	Minn.	Buffalo R.	Secondary	450	
Lake Park	Minn.	Buffalo R.	Secondary	700	
Kennedy	Minn.	Red River	None	200	
Stephen	Minn.	Tamarac Cr.	Primary	650	
McIntosh	Minn.	Poplar R.	Secondary	1,100	
Plummer	Minn.	Clearwater R.	None	300	
Bagley	Minn.	Clearwater R.	Secondary	1,500	

TABLE IV (Cont'd)

Municipality	State	Stream	Treatment Facilities	Est. Pop. Equ. of Waste	Remarks
Finley	N.D.	Sheyenne	Imhoff Tank	700	
Portland	N.D.	Goose R.	None	1,500	No sewer system now
Mayville	N.D.	Goose R.	Imhoff Tank	1,700	
Hillsboro	N.D.	Goose R.	None	2,500	
Hatton	N.D.	Goose R.	Imhoff Tank	800	
Hope	N.D.	Maple R.	None	600	
Minto	N.D.	Forest R.	None	750	No sewer system now
Park River	N.D.	So. Branch Park R.	Septic Tank	2,500	
Grafton	N.D.	Park River	Primary and Filter	1,200	
Cavalier	N.D.	Tongue R.	Septic Tank	1,500	
Pembina	N.D.	Pembina R.	None	1,000	
Walhalla	N.D.	Pembina R.	Primary and Filter	360	
			Total - -	454,667	

As can readily be seen, industrial wastes can easily exceed the population equivalent of the two largest towns in the Basin. Without, therefore, some estimate of the type and quantity of industrial development that will occur in the next half century, it is impossible to ascertain firmly and accurately the amount of dilution water that can be used in the future. In the absence of either a prediction of the municipal population increase, based on the Missouri-Souris development, or the industrial increase, based on the same development, certain plausible assumptions have been made.

4. FLOW REQUIREMENTS

The Red River of the North Research Investigations previously mentioned in this report, estimates required flows at Fargo of 129 c.f.s. in winter and 34 c.f.s. in summer with treatment of wastes existing in 1939, and higher amounts with 85 per cent waste treatment or secondary treatment since the present degree of treatment of certain industrial wastes exceed 85 per cent. The required flows at Grand Forks are reported as 253 c.f.s in winter and 47 c.f.s. in summer without sugar-beet wastes under conditions of then existing treatment, and 112 c.f.s. in winter and 13 c.f.s. in summer without sugar-beet wastes and 85 per cent sewage treatment. The required flow with sugar-beet wastes which occur only in fall and winter is reported as 1081 c.f.s. in winter and 177 c.f.s. in October with then existing treatment, and 305 c.f.s. in winter and 23 c.f.s in October with 85 per cent sewage treatment.

It has been estimated in the same report that a flow of 160 c.f.s. for a period of one month will be required to form an ice cover two feet thick from Fargo to Lake Winnipeg. It is assumed that an additional 40 c.f.s. will be necessary to form the same ice cover from the Sheyenne Dam to Fargo or a total of 200 c.f.s. for a period of one month. This may be required at the time of minimum flow and at the time of a heavey pollution load. According to information received from the Bureau of Reclamation, maximum winter releases might have to be anticipated in time to form an ice cover that will pass these releases without overflow. It appears, therefore, that this 200 c.f.s. must be added to the maximum anticipated flow required, even though during this time, (first month of ice cover), it might not be necessary to provide the maximum flow for sewage dilution purposes. However, whether this 200 c.f.s. should be added to the maximum flow required is a matter for further study and beyond the scope of this report. This 200 c.f.s. is not included in the flow requirement and use figures of this study.

For the purpose of this study the preliminary assumption is made that the population equivalent of the municipal and industrial sewage effluents influencing the stream at Fargo and Grand Forks will eventually be at least twice as great fifty years hence as that existing at the time of the above calculations. This now appears to be a reasonable assumption, especially

in view of the type of industrial development the Missouri-Souris project is expected to foster. It is also assumed that by the time this development takes place, the existing sources of pollution will be subject to 85 per cent or secondary treatment, and that new sources of pollution will likewise have a similar degree of treatment. It is also assumed, as in the Red River of the North Research Report Calculations, that 6 ppm of dissolved oxygen will be available in the dilution water. This is also a subject that warrants field investigation.

The maximum flow required will, of course, control and, on the above basis, it is estimated that this will be approximately 600 c.f.s. at Grand Forks some fifty years hence.

The minimum monthly mean winter flow that can be expected once in ten years at Grand Forks is 80 c.f.s. There should, therefore, be available 530 c.f.s. of dilution water to be diverted from Sheyenne Dam for a minimum period of one month, and lesser amounts for extended periods at more frequent intervals for winter conditions. The above amount represents the minimum that should be available under the above conditions at Grand Forks. The actual diversion required may be considered in excess of this, since in this report no consideration can be given to stream losses due to seepage, formation of ice cover, etc. The maximum required summer flow will be at Fargo. This will consist of 34 c.f.s. for the existing (1939) load plus an estimated 100 per cent increased load which, it is assumed,

will receive 85 per cent treatment and require 48 c.f.s., or a total of 82 c.f.s. Since the minimum monthly mean flow that occurs once in ten years at Fargo is 5 c.f.s. and zero for a once in twenty-year frequency, there should be available approximately the entire required flow, or 80 c.f.s. at Fargo for summer conditions. Here no consideration can be given to losses, and actual diversion may need to be considerably greater. If sewage treatment facilities that will remove 85 per cent of the biochemical oxygen demand of all the sewage are not provided, the required flows will, of course, be considerably greater than these. Since the above calculations assume a 6 ppm dissolved oxygen concentration in the dilution water, it may well be necessary to provide aeration of the water as it is released from the dam or to provide some type of downstream aerating device. This, too, is a subject that requires further study.

The flows required at the present time are calculated on the basis of a 20 per cent increase in sewage load from the 1939-1940 level to date. On this assumption the required winter flow at Grand Forks with sugar-beet wastes would be approximately 1300 c.f.s. or 1220 c.f.s. additional flow to be provided for a period of at least one month once in ten years and lesser amounts at more frequent intervals. Without sugar-beet wastes this may be reduced to approximately 300 c.f.s. The controlling required summer flow is estimated on the same basis to be 56 c.f.s. at Grand Forks. On

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the basis of low flow frequencies, this entire flow should be available at Grand Forks. Here again no account of losses is considered and greater flows would have to be released from the dam.

5. BENEFITS

The general method of computing minimum tangible benefits has been discussed above. The value of the required dilution water for stabilization of the effluents from sewage treatment plants effectuating 85 per cent removal of the biochemical oxygen demand has been equated to the cost of providing tertiary treatment units that will produce comparable results. These costs are based on figures prepared by the North Dakota State Department of Health for sedimentation basins and sand filters. They have been adjusted from the 1937 price level to the 1948 price level on the basis of the Engineering News Record Construction Cost Index. The total capital cost of tertiary treatment units was calculated on a conservative basis and does not include many of the smaller cities located some distance from the main stem of the Sheyenne and Red Rivers. It is possible that a more detailed study will indicate some benefit should be included for these cities. However, because of the gross assumption that the population equivalent of effluents will double some fifty years hence, this omission is considered reasonable. The capital cost of the tertiary treatment units that would produce results comparable to the increased required flows in the Sheyenne and Red Rivers is taken to be $6,000,000.

Annual benefits are calculated on the basis of maintenance and operation charges of 3 per cent, interest charges at 3½ per cent and amortization of obsolescence at fifteen years. It is realized that fifteen years may be a somewhat shorter amortization period than usual, but this figure is chosen because of the rigors of the severe winter, the deleterious effect of frequent alternate freezing and thawing that accompanies operation of intermittent sand filters, and the fact that this type of treatment unit usually receives inadequate attention.

On the above basis then, the minimum tangible annual benefits that can be assumed as the result of providing the "required flow" some fifty years hence is approximately $700,000. There are, of course, many other benefits which, although virtually impossible to assess by rational methods, are quite important. These include benefits to recreation, fish and wildlife, riparian farms, esthetic values and public health. Likewise, no value is assigned to the great benefits that will accrue as the result of industry that requires extensive sewage dilution water, being able to locate in the Basin. Intensive detailed study in conjunction with Bureau of Reclamation economists and reliable predictions of future industrial development may evolve a rational method for calculating such benefits.

VI - GENERAL DISCUSSION

It is desired to emphasize that this report is to be considered as tentative, subject to revision, and is for the confidential use of the Bureau of Reclamation. As is implied in the section entitled, "Recommendations for Further Studies," many important facts are not available for this report. Some can be obtained only by field investigation of a detailed nature, some must be obtained by research, and some must be evaluated on the basis of cooperative study and evolvement of methods not now available.

Unfortunately, many of the important benefits are intangible and do not lend themselves readily to rational analysis. One of these benefits, for instance, is the extensive physiological and psychological implications on the health of human beings as the result of security, stable income, better diet, and a more adequate and better quality drinking water supply through the provisions of a project such as the vast Missouri-Souris development. The improved health allows the individual to increase the span of his productive ability and to increase his unit-time production. Such values as these, could they properly be evaluated, would be enormous.

It is realized that some discussion concerning the feasibility of diverting water through Devils Lake in order to reestablish it as a fresh water lake is desired by the Bureau. In order to present detailed computations and figures that will be useful, it will be necessary to carry out some, perhaps extensive, field

study. The amount and kind of deposited salts must be ascertained. The amount and chemical quality of diversion water must be determined. Likewise, temperature and mixing patterns must be estimated. All this and other data must be available before the desired information can be furnished.

It can, however, be stated that diversion of fresh water through Devils Lake will eventually reestablish it as a fresh water lake. Furthermore, such diversion should not exceed in quantity the amount that would produce, when mixed with Sheyenne and Red River water: concentrations of sulphates and chlorides in excess of 500 ppm each, and preferably not more than 250 ppm each; concentrations of total dissolved solids not in excess of 1000 ppm but preferably not more than 500 ppm; and phenolphthalein alkalinity (calculated as $CaCO_3$) not to exceed 15 ppm plus 0.4 times the total alkalinity. This limits the permissible pH to about 10.6 at 25° C. Depending upon the normal carbonate alkalinity, which should not exceed 120 ppm and the total alkalinity, the pH may be limited to a range of 8.0 to 10.6 at 25° C.

Consideration has not been given to the Bald Hill Dam and Reservoir, now under construction, in the calculation of benefits for the Sheyenne Dam and Reservoir. The effect of Bald Hill Reservoir on Sheyenne Reservoir is not apparent because of the many functions Sheyenne Dam seeks to serve. Plans for Bald Hill Reservoir apparently were not coordinated with the proposed larger

structure at the time construction was started. It is assumed that plans for coordination of the two structures will be developed before Sheyenne Dam goes into the construction stage. Similarly, consideration was not given to the decreased benefits that might accrue as a result of the released water by-passing whatever downstream (James or Missouri River) power plants either existing or as planned for future (2000 A.D.) development.

A more detailed report than this should give attention to the flows that may be required in October which is a period during which sugar-beet factories are operating and during which low but not minimum flows may occur. It is possible that combinations of circumstances that could occur with a given frequency might require additional "summer" or open water flows in excess of required "summer" flows.

In a report prepared by the North Dakota State Department of Health and the Office of the State Engineer in 1939, the annual benefits to water and sewage of diverting Missouri River water into the Red River basin were estimated at $750,000. Since annual benefits to "water and sewage" are estimated to be only $1,140,000 in this report, with construction costs almost double those of the 1939 era, it becomes evident that the preliminary nature of this study has forced conservative estimates. It is realized that the scope of the project envisioned today is somewhat broader than in 1939. This lends further credence to the fact that benefit estimates herein contained represent minimum figures.

VII - RECOMMENDATIONS FOR FURTHER FIELD STUDIES

This study clearly indicates that certain work needs to be completed before the best possible answers to the questions proposed in the section entitled, "Scope," can be ascertained. Throughout this report repeated reference has been made to information that must be obtained before a report more detailed than this can be developed. This section is included to briefly acquaint those concerned with the extent and magnitude of investigations which must be undertaken in order to prepare a final report.

It will be necessary to obtain more detailed field information on the water and sewerage works of each community involved, along with information about communities that do not now have public water and sewerage systems. This includes accurate estimates of existing industrial water supply demands and sewage effluent strength, volume and character.

It will be necessary to predict as accurately as possible future population increases, both urban and rural. Likewise, the prediction of the number, size, location and character of industrial development in the future will be a critical need. It may be essential that this information be supplemented by extensive sampling of the major streams for chemical, bacteriological and physical analyses accompanied by concurrent gaging information. This should extend over a period of several months to include both winter and summer seasons, and may include many significant sources of

pollution about which little is presently known. The usefulness of this data would be greatly enhanced if certain biochemical research is included in the analytical program. Certain biological investigations of the streams should also be included.

If the desired answers are to be furnished concerning Devils Lake, field and analytical data previously described will be required. Such data are not believed to be available at this time.

Some considerable effort should be devoted to a study of the suitability of the probable quality of stored water for sewage dilution and water supply, along with studies pertaining to dissolved oxygen concentrations in the released water, and the extent of available dissolved oxygen in the dilution water downstream under conditions of ice cover. These should be correlated with studies relating to the economics of low head downstream dams for winter aeration purposes and perhaps model studies of such dams to determine the efficiency of various designs for increasing aeration.

It appears that further study and consideration should be given to minimum acceptable dissolved oxygen concentration in the stream under winter conditions. The effect of existing sludge deposits on winter and summer oxygen demands needs evaluation along with the widely varying oxygen demand that these deposits apparently exert with broad fluctuations in flow and temperature.

Some field investigations will be necessary, perhaps in other

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but similar areas where irrigation now exists, to properly evaluate benefits to rural water supply as the result of the recharge or creation of an underground potable water source.

The evaluation of losses in the stream due to seepage, transpiration, evaporation and consumptive use will be a requisite for the translation of required flows at a particular point to reservoir storage capacities and releases. Some field investigations and analyses may be required to adequately estimate the effect of rural or "natural" pollution on the streams. All these and many other factors must be determined by experienced personnel capable of duly considering and evaluating such information. It is indeed a task that will tax the ability of sanitary and hydraulic engineers, chemists, bacteriologists, biologists, economists, and others.